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**HELICOPTER PILOT BACK PAIN: A PRELIMINARY STUDY  
(Reprint)**

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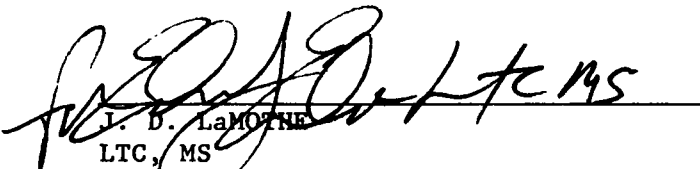
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Because of the high prevalence of back pain experienced by U.S. Army helicopter pilots, a study was conducted to ascertain the feasibility of reproducing these symptoms in the laboratory. A mock-up of a UH-1H seat and control configuration was mounted to a multi-axis vibration simulator (MAVS). Eleven subjects were tested on the apparatus for two 120-min periods. During one period, the MAVS was programmed to reproduce vibrations recorded from a UH-1H in cruise flight. The subjects received no vibration during the other test period. All subjects reported back pain which they described as identical to the pain they experience during flight, during one or more of their test periods. There was no statistical difference between the vibration and nonvibration test conditions ( $p > 0.05$ ) in terms of time of onset of pain or intensity of pain as measured by a visual analog scale. It appears the vibration at the frequencies and amplitudes tested plays little or no role in the etiology of the back symptoms reported by these pilots. It is proposed that the primary etiological factor for these symptoms is the poor posture pilots are obliged to assume for extended periods while operating helicopters.

# Helicopter Pilot Back Pain: A Preliminary Study

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Because of the high prevalence of back pain experienced by U.S. Army helicopter pilots, a study was conducted to ascertain the feasibility of reproducing these symptoms in the laboratory. A mock-up of a UH-1H seat and control configuration was mounted to a multi-axis vibration simulator (MAVS). Eleven subjects were tested on the apparatus for two 120-min periods. During one period, the MAVS was programmed to reproduce vibrations recorded from a UH-1H in cruise flight. The subjects received no vibration during the other test period. All subjects reported back pain which they described as identical to the pain they experience during flight, during one or more of their test periods. There was no statistical difference between the vibration and nonvibration test conditions ( $p > 0.05$ ) in terms of time of onset of pain or intensity of pain as measured by a visual analog scale. It appears the vibration at the frequencies and amplitudes tested plays little or no role in the etiology of the back symptoms reported by these pilots. It is proposed that the primary etiological factor for these symptoms is the poor posture pilots are obliged to assume for extended periods while operating helicopters.

**T**HE HIGH PREVALENCE of back pain in helicopter flight crews has been documented in numerous studies over the last 25 years (3-5,11,13,14). Most of these studies reported prevalence rates in excess of 50%, and many reported prevalences exceeding 75%. Most authors agree that once an individual experiences the onset of back pain associated with his flight duties, the pain tends to become chronic and is related to the frequency, duration, and nature of his flight missions (3,4,14). Indeed, there appears to be an exposure threshold that fairly consistently will produce symptoms in a given individual. Although the lifetime incidence of low-back pain in industrialized societies has been reported at 60-80% (15), the pattern of pain reported by the general population appears to be considerably different from that of

helicopter flight crews. Most nonaviators report acute intermittent pain episodes of variable duration separated by extended periods of time, frequently years, when they are completely asymptomatic. The activity or event that triggers a new episode of pain frequently cannot be identified or anticipated, unlike the pain reported by helicopter crewmembers. Clearly, there are one or more factors in the helicopter flight environment that produce a high prevalence of back pain in helicopter crewmembers.

The two factors most widely implicated in the etiology of back pain in helicopter crewmembers are vibration and posture (3-5,14). To date, the evidence supporting vibration as a major causal factor has been largely subjective and conjectural. Helicopters subject their occupants to vibration over a frequency range that coincides with the resonant frequency of the spinal system (3,6,15). However, it remains uncertain what the pathological effects of chronic, intermittent exposure to this level of vibration may be over the short and long term; specifically, what contribution such exposure makes to the etiology of the back pain experienced by helicopter crewmembers. Most studies suggesting a higher prevalence of back pain in occupations with high levels of vibration are associative studies; causation cannot be inferred since these studies fail to control the many other factors that might contribute to a higher prevalence of back pain in particular occupations. Possible contributing factors include seating position, opportunity for shifting posture, and the multiplicity of variables that fall under the general category of lifestyle. Until these factors can be controlled in an experimental environment, the role of vibration in the production of musculoskeletal symptoms and pathology will remain unclear.

On the other hand, the data implicating posture in the etiology of helicopter crewmember back pain are considerably more convincing. It is well documented that the seat and control configuration in most helicopters force the pilot to bend forward in his seat and lean slightly to the left (3,14). Furthermore, the pilot must maintain this position during

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most of the time he is at the controls, since full control of the aircraft requires simultaneous input from all four extremities. The constantly maintained, asymmetrical position does not permit relaxation of the spinal musculature and is, according to Sliosberg (14), a major source of discomfort. Keegan also stresses the importance of poor sitting posture and the resultant straightening of the normal lumbar lordosis to the genesis of low-back pain (7). Delahaye and Auffret cite the comfort angles proposed by Wisner and report that when the seat is constructed so as to allow the flying position to conform to these angles, and the controls are positioned such that the pilot is not required to bend forward and to the left, pilots subjectively give the aircraft higher ratings on comfort than for the aircraft with more typical seat and control configurations (3). Whether such a cockpit design reduces the prevalence of back pain, prolongs its onset, or reduces its intensity or duration are not specifically addressed.

If the problem of back pain in helicopter crewmembers is to be alleviated, it will be necessary to better identify the various etiological factors producing this pain and to evaluate the relative importance of each factor separately. Once the etiology of the pain is better understood, means of eliminating the problem can be developed. As an expedient toward this goal, it would be useful to develop a model whereby the characteristic low-back pain of helicopter pilots could be consistently reproduced in a laboratory. If the pain can be reproduced, then the various etiological factors can be isolated and manipulated. This paper will describe such a simulation and give some preliminary findings on the relative importance of vibration in producing helicopter pilot back pain.

## MATERIALS AND METHODS

A seat and control mock-up was constructed to the cockpit dimensions of a UH-1H helicopter (Fig. 1,2,3); the spatial relationships between the seat and all controls on the mock-up were identical to an actual UH-1H. The mock-up was mounted on the United States Army Aeromedical Research Laboratory (USAARL) Multi-Axis Vibration Simulator

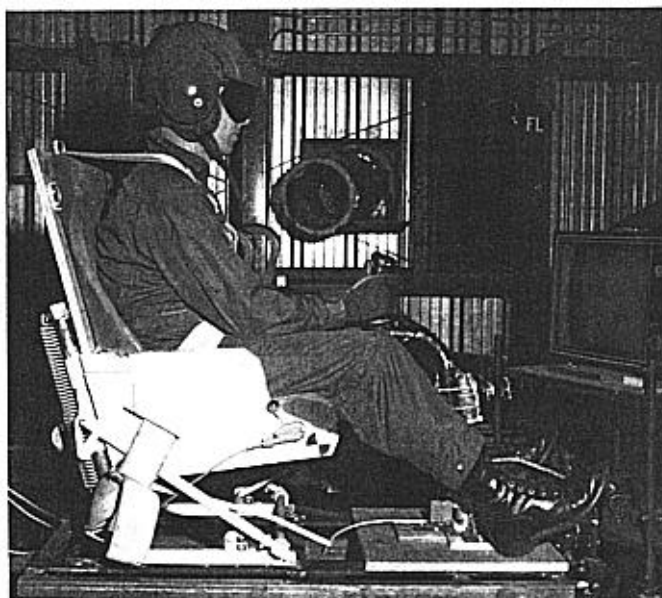


Fig. 1. Right side view of pilot in UH-1H mock-up.

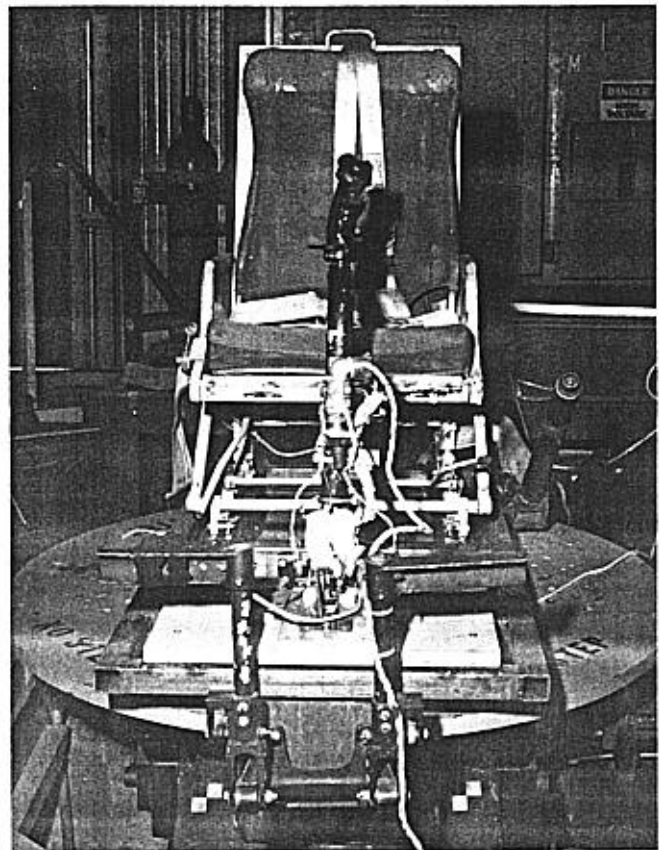


Fig. 2. Front view of UH-1H mock-up on MAVS.

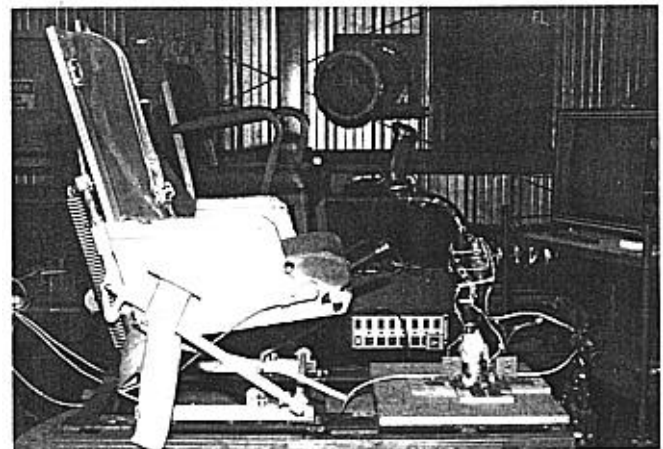


Fig. 3. Right side view of UH-1H mock-up on MAVS.

(MAVS). Through a taped input, the MAVS was programmed to reproduce the vibration measured from the floor adjacent to the pilot's seat rail of a UH-1H helicopter in cruise flight. Although the UH-1H in cruise flight produces a complex spectrum of vibration at the pilot stations, the predominant components of the spectrum are due to the rotation of the main rotor system. Laing (9) has measured and analyzed data collected from various locations in the cockpit and found the most prevalent frequencies to be the 2/rev (10.8 Hz), 4/rev (21.6 Hz), and 6/rev (32.4 Hz) components of the main rotor frequency in cruise flight (5.4 Hz). He, furthermore, showed that the acceleration plus 3 standard deviations, which is the calculated acceleration below which

99.87% of the data fell, was 0.28 g at 10.8 Hz and 0.35 g at 21.6 Hz. These accelerations are quite small; however, it should be noted that the 2/rev frequency (10.8 Hz) falls within the second resonant frequency of the spinal system of a seated human subject (15).

The cyclic control stick was instrumented to act as a control for an Atari video game set by mounting four microswitches at the base of the cyclic oriented 90° from each other (Fig. 4) and utilizing the microphone switch in the handle of

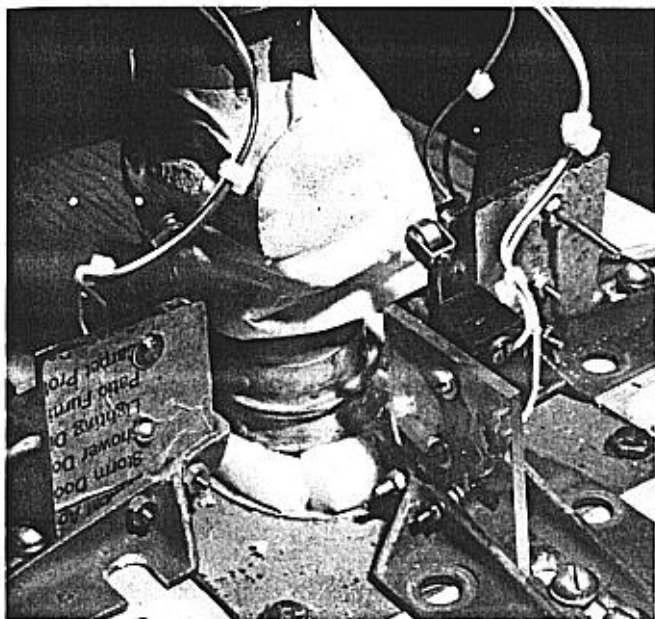


Fig. 4. Close-up view of microswitches mounted to base of cyclic.

the cyclic as a firing control. In this manner, the subject was able to utilize the cyclic control to play an assortment of Atari games to keep himself occupied at roughly the same concentration level as would be required to actually fly a helicopter. The right pedal of the mock-up was instrumented with a pressure-sensitive switch that would automatically shut down the MAVS if foot pressure were released. This is a safety feature that allows the subject to terminate the experiment immediately at his own discretion in the event of a system malfunction or if he experiences sudden onset of extreme anxiety or discomfort. The remainder of the flight controls were not instrumented but were fully movable as in an actual UH-1H helicopter.

The 11 subjects selected for this study all reported that they frequently experienced back discomfort while flying the UH-1H helicopter for periods of less than 2 h. Each subject was tested for two separate 120-min periods, one with vibration and one without. The initial test condition, i.e. with or without vibration, was randomly assigned and the two test periods were separated by no less than 24 h. Additionally, no test subject was retested until he reported that he was completely free of any residual back discomfort. During the test period, the subject was dressed in standard U.S. Army flight gear consisting of flight suit, boots, flight gloves, and flight helmet. He was in constant communication with the MAVS operator through an intercom system connected to the integral communication system of the flight helmet. The subject was instructed to adjust his seat and the controls as he would normally, and to keep both feet on the pedals and

his right hand on the cyclic control throughout the test period. He was allowed to intermittently remove his left hand from the collective control for brief periods and shift his sitting position as he would if he were actually flying a helicopter in cruise flight. During the experiment he could play his choice of various Atari games at whatever pace he chose.

The subject was instructed to report the onset of any back discomfort, and this time was recorded as minutes into the experiment. At the end of the 2-h period, the subject was requested to fill out a short questionnaire on his activities over the preceding 24 h and to the nature, location, and intensity of the discomfort he noted during the experiment. Pain intensity was measured subjectively by employing a visual analog scale (VAS). In this method, the subject was presented with a 100-mm straight line labeled with "no pain" at the left end and "excruciating pain" at the right. The subject was instructed to place an "X" on the spot that best corresponded to the maximum intensity of pain he experienced during the test period. Pain intensity, therefore, was measured in millimeters from the origin of the VAS to the mark placed by the subject.

## RESULTS

The experimental conditions produced back pain in all 11 test subjects. Each subject reported the pain identical to the discomfort when actually flying a UH-1H helicopter for similar periods of time. Table I summarizes the age and anthropometric measurements of each of the test subjects and gives the percentile rating of each measurement (1).

Table II summarizes the onset time and pain intensity for both vibration and no-vibration test conditions for each subject. All subjects reported pain under both test conditions, except subject 7 who reported no pain in the no-vibration test. Nevertheless, this same subject indicated a low level of discomfort for the no-vibration experiment by marking the VAS at 7 mm. The results of both univariate and multivariate statistical testing of the data in Table II indicated no significant difference between the vibration and no-vibration conditions for either onset time or intensity of pain. Nonsignificant results occurred regardless of whether subject number 7 was included or excluded from the analysis. There also was no statistically significant effect for sequence of exposure to the vibration and no-vibration test conditions.

## DISCUSSION

The UH-1H cockpit mock-up used in this study was extremely effective in reproducing the back discomfort test subjects state they experience while actually flying a helicopter. All the subjects reported the pain they experienced in the mock-up was qualitatively and quantitatively identical to the pain they experience in actual flight. The pain was uniformly described as a dull ache or numbness (average intensity = 33) confined to the lower back and/or buttocks without radiation into the legs. This description is consistent with the description of back pain in a recent survey among 802 U.S. Army aviators, in which a 73% prevalence rate of back pain was reported (unpublished observations). Consequently, the subjects selected for this study appear to be fairly representative of Army aviators in terms of the nature of the pain they experience while flying.

A review of Table I reveals that the mean age, stature, and sitting heights of the subjects were considerably above

TABLE I. ANTHROPOMETRY OF SUBJECTS.

Subject Number	Age* (yrs)	Stature* (cm)	Weight* (kg)	Sitting Height* (cm)	Buttock-knee Length* (cm)	Functional Reach* (cm)
1	35 (92)	187.2 (97)	77.3 (50)	97.3 (97)	63.5 (90)	83.8 (86)
2	34 (90)	184.2 (94)	75.0 (43)	98.8 (97)	61.2 (65)	82.8 (80)
3	34 (90)	170.9 (29)	70.9 (27)	88.4 (20)	57.9 (20)	79.8 (55)
4	22 (24)	183.9 (93)	81.8 (67)	92.7 (70)	63.0 (85)	84.3 (90)
5	25 (54)	174.5 (50)	72.3 (33)	92.4 (70)	57.4 (15)	79.5 (55)
6	32 (86)	168.9 (18)	66.3 (17)	91.4 (55)	56.1 (06)	77.2 (32)
7	28 (74)	178.6 (75)	79.6 (54)	94.0 (82)	56.7 (10)	77.9 (40)
8	26 (64)	176.6 (14)	63.6 (10)	91.4 (70)	57.1 (14)	78.7 (46)
9	31 (84)	185.7 (96)	81.8 (67)	97.0 (97)	63.0 (85)	83.1 (82)
10	33 (88)	177.8 (70)	83.2 (70)	94.5 (86)	58.4 (25)	77.4 (35)
11	34 (90)	176.5 (63)	77.3 (50)	91.9 (65)	60.2 (50)	78.5 (45)
Mean	30.4 (80)	178.62 (75)	75.4 (45)	93.6 (80)	59.5 (40)	80.3 (62)
± 1 S.D.	± 3.9	± 5.7	± 5.8	± 3.5	± 2.7	± 1.5

\* Numbers in parentheses represent approximate percentile of measurement (1).

average for U.S. Army aviators (1). Even though the subject population tended toward older, taller individuals, it can be seen that the range of the measurements in Table I also included much lower percentile individuals. Furthermore, there was no significant relationship between any of these variables and either the time of onset or intensity of pain as shown by Pearson product moment correlation coefficients. This is probably because the seat and pedals in the UH-1H are designed to allow sufficient adjustment to accommodate approximately the 5th to the 95th percentile male. Thus, most aviators are able to adjust the seat and pedals so as to achieve identical relative position with respect to the controls.

An extremely interesting finding of this study was that the presence of simulated helicopter vibration had no significant influence on the time of onset or the intensity of pain reported by the experimental subjects (Table II). In spite of the relatively small number of subjects used in this study, the results are convincing. Vibration at the frequencies and amplitudes tested appeared to play little or no role in the etiology of the back pain experienced by these subjects.

In the investigators' opinion, the major etiologic factor in the rather stereotyped back pain reported by helicopter pilots is posture. Pilots are forced to assume a slumped and asym-

metrical position for extended periods of time with little chance to significantly change their position. This situation probably leads to spasm of paraspinal musculature and increased pressure sensitivity of the buttocks. This hypothesis is supported by the fact that, for the majority of aviators, these symptoms are extremely transient usually disappearing within several hours of the termination of the flight. Furthermore, the symptoms do not recur until the next flight, nor do these aviators typically report other activities that provoke similar episodes of pain (unpublished observations).

Unfortunately, the reporting of pain is purely subjective. To date, no objective means has been developed to reliably detect or quantify lower-back pain. Nevertheless, extensive work has been done in developing and validating subjective pain scales. The VAS has been cited as one of the best "paper-and-pencil" instruments available for assessing clinical pain intensity (8). The advantages of the VAS are that patients produce a uniform distribution of intensities in clinical trials, VAS pain estimates are highly reliable on repeated measurements, the VAS is sensitive to changes in pain intensity, and variance due to affectual factors is small (2,8,9,11,16). The one main disadvantage of the VAS shown in clinical trials is that it requires an alert patient with intact

TABLE II. TIME OF ONSET AND INTENSITY OF BACK PAIN.

Subject Number	Initial Test Condition	Vibration		No Vibration	
		Onset Time (min)	Intensity (VAS)	Onset Time (min)	Intensity (VAS)
1	Vibration	60	10	70	26
2	Vibration	20	40	60	35
3	No Vibration	80	16	100	14
4	No Vibration	100	30	90	51
5	Vibration	90	17	90	23
6	No Vibration	75	34	90	45
7	Vibration	70	31	—	7
8	Vibration	55	35	45	38
9	No Vibration	90	42	80	40
10	No Vibration	35	38	40	42
11	No Vibration	40	48	30	45
Mean ± 1 S.D.†		65.0 ± 23.5*	31.0 ± 11.4**	65.5 ± 31.6*	35.9 ± 10.9**

† Mean for no-vibration test condition based on N = 10, subject #7 excluded.

\* Difference is nonsignificant,  $p > 0.05$ .

\*\* Difference is nonsignificant,  $p > 0.05$ .



faculties for abstract thinking (8). This is not a problem in the population of young, healthy aviators used in this study. Consequently, we will continue to rely on the VAS for measuring pain intensity in this type of study while, at the same time, exploring the use of surface electrode electromyography as a potential objective measure of lower-back pain intensity in helicopter pilots.

Clearly, this study is only preliminary. However, a method of reproducing helicopter pilot back pain in a controlled environment has been developed and found to be promising in this application. Further studies are planned to vary seat and control locations and configurations to determine the relative importance of these variables in the etiology of helicopter pilot back pain. The relative importance of vibration also will continue to be explored. It is expected that, through this program, the various etiological factors contributing to the high prevalence of back pain in helicopter pilots can be identified and design criteria developed to substantially mitigate the problem.

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